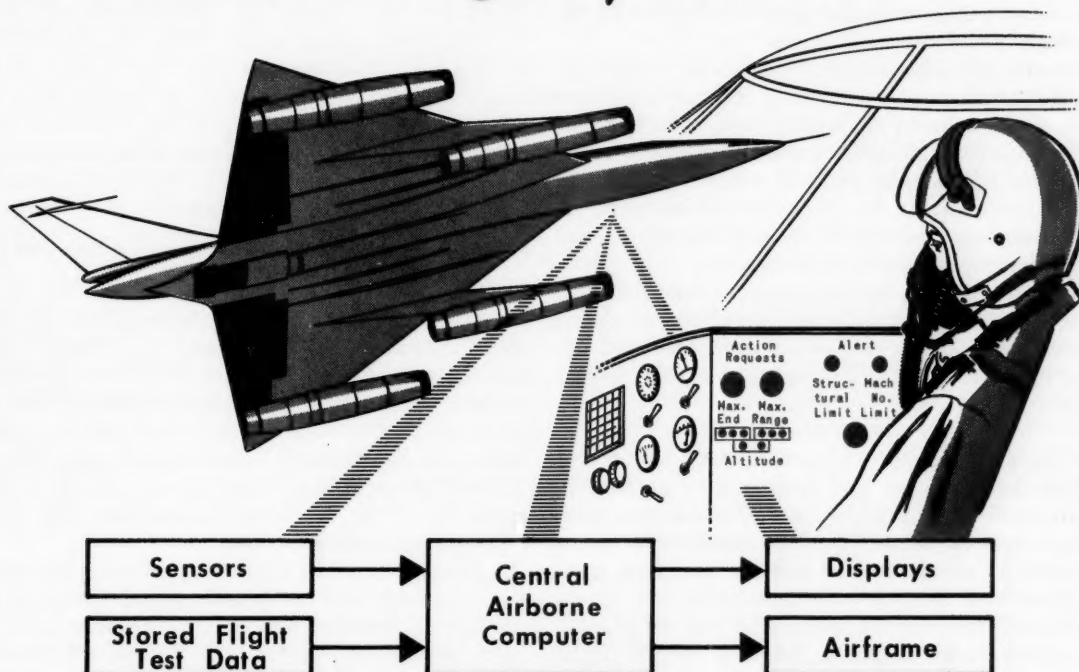




## research trends

CORNELL AERONAUTICAL LABORATORY, INC., BUFFALO 21, NEW YORK

### *The Airborne Computer....*



Artist's conception of the airborne digital computer. Sketch of a typical supersonic bomber aircraft in which the computer might be used is shown at left. At right is the computer display shown on a panel in the cockpit. Simple block diagram of the computer system is shown below.

by DR. MORTON G. SPOONER

#### CAL Studies Applications of Digital Computer in Manned Aircraft

**M**ANY high-speed digital computers are truly electronic giants in size as well as speed. An interesting development has come about, however. Although their speeds and capacity continue to increase, computers are being developed that are physically smaller and more compact. As a result, new applications arise for general purpose units which can now operate in real-time situations as part of extremely complex, closed-loop systems. Their speed is such that the small delays associated with computers do not normally deter the operation or the stability of the control system.

Capability of these high-speed computers makes them suitable for many types of problems; their relatively small size makes their use feasible on ships, sub-

marines, and aircraft. In these applications the digital computer can become a central computational facility.

Such a facility in an aircraft has many advantages. Several of the special purpose computers can be replaced. Maintenance of a single computer is easier; reliability is thereby increased. In many cases the presence of the computational facility makes possible valuable aircraft subsystems that would not be otherwise feasible.

#### IBM Sponsors Computer Study

The International Business Machines Corporation, Owego, New York, realized the value of a central computational facility as a part of future manned aerial

and spacial craft. In 1958 it initiated at Cornell Aeronautical Laboratory a study of several of the applications of an airborne digital computer. The study did not include the functions of bombing, navigation and other weapon delivery systems — applications which comprise about 50% of the important uses of such a facility. Rather, it investigated capabilities which had not been explored. The results of this study, carried out jointly by the Electronics, Applied Physics and Flight Research departments, clearly indicate the potential advantages in a manned aircraft of a central computational facility operating on a time-shared basis. The study also indicates that the proper use of an airborne digital computer makes possible fuller use of the capabilities of the aircraft.

Consider the manned multi-jet bombers that are and will continue to be a part of our continental defense system. From take-off to landing, optimum performance is difficult to obtain without considerable reference to flight handbook data. In many instances, the data are too complex for the crew to interpret. A central computer can aid the mission by storing and acting upon these stored aircraft data.

Optimum aircraft performance is not the only objective for the properly programmed central digital computer. Monitoring the present and predicted operating limits of the aircraft can be an equally important job.

#### Take-Off Monitoring

With the advent of high performance jet aircraft, the margin of safety available to a pilot during a take-off maneuver has decreased substantially. The thrust characteristics of the engines and the increased speed requirements of take-off have drastically reduced the time available for the pilot to assess his take-off progress and implement his decision. Thus, a central digital computer can be valuable to the pilot during this critical maneuver.

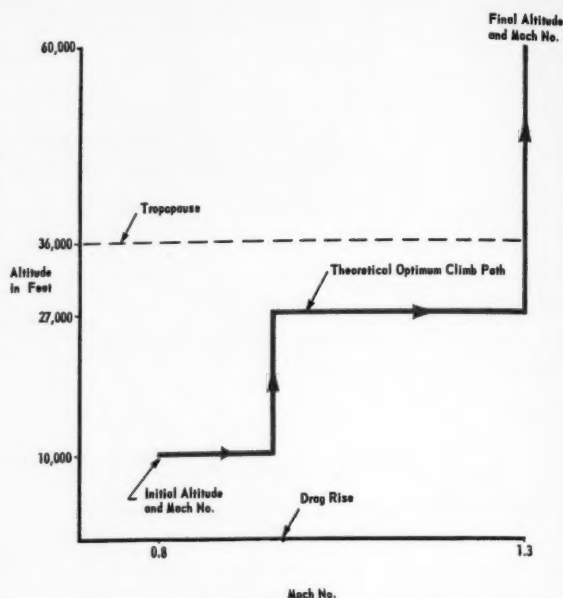


FIGURE 1 — A typical, minimum-time climb path used by the airborne computer.

At present, commercial airline pilots proceeding down the runway during take-off are informed of two significant airspeeds,  $V_1$  and  $V_2$ . The airspeed  $V_1$ , arrived at through many approximations, is the maximum airspeed at which a safe stop can be made in the remaining runway. Once this airspeed has been reached, the pilot must continue the take-off. The airspeed  $V_2$  is the minimum airspeed for safe take-off with one engine inoperative.

The results of the CAL study of computer applications indicate that a central digital computer in a modern jet bomber would make possible more complete monitoring of the critical take-off maneuver. Two quantities that can be determined easily by the computer are useful to the pilot: one, a prediction of the excess runway available after achieving the take-off air velocity; the other, a determination of runway required for the aircraft to come to a complete stop.

These quantities are functions of many variables, such as present acceleration, predicted acceleration, aircraft characteristics, runway slope and friction coefficient, present airspeed, braking characteristics, and others. The computer thus would give a pilot more complete monitoring of his take-off, indicate his progress, and predict what will happen if (1) he continues on or (2) if he decides to abort the take-off.

#### Climb Control

The central computer in a jet aircraft would not be idle long after take-off, for normally after this initial maneuver the aircraft climbs to its cruising altitude. During the climb large amounts of fuel are used and the pilot should choose a climb carefully so that he optimizes it according to some chosen criterion.

A pilot does not now have sufficient aid to fly optimum or near-optimum flight paths during climbs. For the most part, he memorizes the best climb speeds as

#### THE COVER

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An important facility at CAL is the Philips EM-100B electron microscope, acquired last year for research in materials, applied physics and electronics. Photo insert at left and on page 1 illustrates one of the many uses of the microscope: detailed examination of the structure of high-temperature, lean alloys now being developed at

CAL. The microscope is capable of nearly 100,000 direct electronic magnification and can resolve detail at least 100 times as small as that resolvable by conventional light microscopes.



a function of altitude; occasionally he refers to his flight handbook for climb data. Typically, a pilot does know his optimum cruising altitude and airspeed but he does not pay much attention to the path he follows to obtain his cruise conditions. In any event, climb procedures are rather haphazard and no attempt is made to display automatically to the pilot the proper climb speed.

The pilot's job of approximating an optimum climb is made even more difficult by high-performance aircraft, which can increase their airspeed while climbing, climb at speeds above Mach 1.0, and cruise above the tropopause (that portion of the atmosphere directly below the stratosphere). The pilot could not possibly memorize all the details of the proper climb nor constantly refer to the flight handbook for this information, if he intends to choose the optimum climb path. Considerable effort has been expended in the last fifteen years to determine the optimum climb techniques of high-performance aircraft. The CAL study of the applications of an airborne digital computer included an investigation of many of the analyses which had been made.

To determine optimum climb paths the CAL study used the technique of dynamic programming as developed by Bellman at the Rand Corporation. An IBM 704 digital computer at CAL did the necessary computations in this multi-decision process. The characteristics of a hypothetical supersonic aircraft were used in the study. In Figure 1, a typical, minimum-time climb path, obtained as a result of the computer program, is

An airborne digital data processor can be used, however, to more nearly optimize the climb by storing pre-calculated optimum climb paths in its memory. The computer, upon being informed of the prescribed end conditions of the climb, could sense such present conditions as altitude, Mach number, and aircraft weight, and refer to a set of normalized climb curves to control the autopilot or to inform the pilot of the best climb rate or airspeed as a function of altitude. Considerable savings in fuel or time could be realized by this rather simple application of an airborne digital data processor.

### Cruise Control

A central airborne data processor can be of great aid during the cruise portion of a mission as a fuel management computer. Essentially, the computer can supply the pilot with three classes of pertinent data. These are:

- Primary cruise control data, which include determination of the altitude and airspeed for maximum range or endurance.
- Predicted performance characteristics, which include the range or endurance available under present conditions.
- Emergency fuel management procedures.

A primary cruise-control device can be one of two types. A programmed or invariant-parameter system relies entirely on flight-test data as established in a flight handbook for a particular type of aircraft.\* No allowance is made for differences in performance among aircraft.

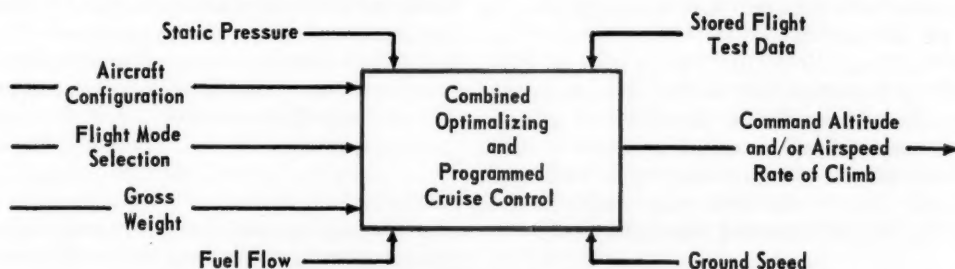


FIGURE 2 — A central airborne computer can serve as a cruise-control system in flight. Such a system is illustrated above.

plotted in an altitude-Mach number plane for an aircraft climbing from Mach 0.8 and a 10,000 ft. altitude, to Mach 1.3 and 60,000 ft. altitude.

Besides the time required for the optimum climb path, the times required for some other typical climb paths were determined in the CAL study.

### Results of this Study

Several conclusions resulted from this study. They are:

- Optimum climb paths are complex, and rather small deviations from them can be costly.
- The drag rise at Mach 1.0 and the tropopause (at approximately 36,000 ft.) greatly influences the characteristics of the optimum climb.
- Optimum climb paths cannot be easily computed in-flight by an airborne digital computer.

A second type of cruise-control system is of the optimizing type where in-flight measurements of ground velocity and fuel flow are used to arrive at a value of instantaneous range. This range can be maximized if altitude and Mach number can be varied. All environmental aircraft and power-plant factors that affect cruise can be assessed automatically and continually in flight. But system stability problems are serious because of aircraft dynamic characteristics and atmospheric turbulence.

As one can readily see, each of the primary, cruise-control schemes has its advantages, and a cruise-control system which is both programmed and optimizing is most advantageous. A system of this type is shown in Figure 2 to indicate the inputs and outputs that would

\*Programmed in this sense means that optimum cruise parameters are stored in the computer.



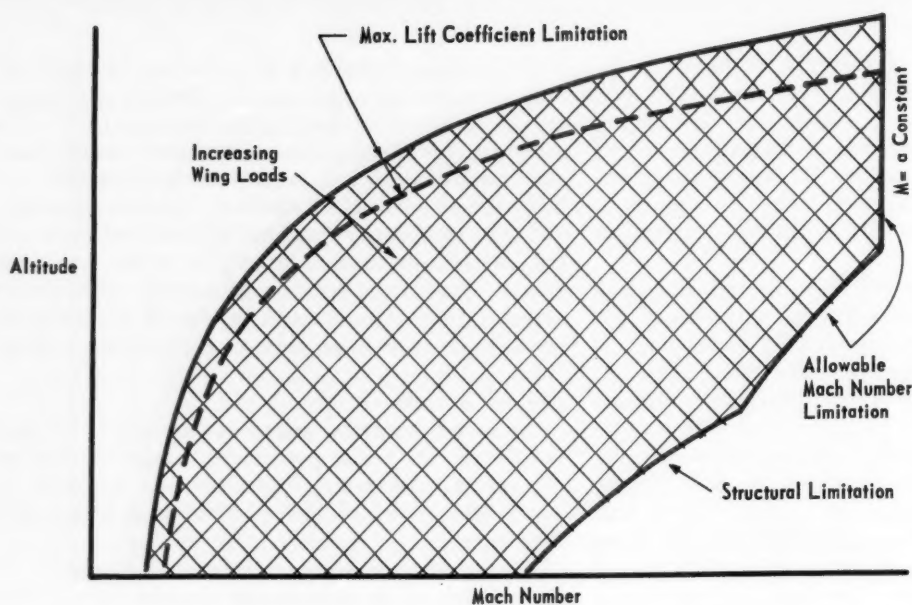


FIGURE 3 — Operating limits of an aircraft can be monitored by the airborne digital computer through implementation of an altitude-Mach number plot, as shown above.

be normally required. An important point to note is that the programmed system is included to stabilize the optimizing system.

The central computer could help the pilot considerably by calculating data on predicted performance. Based upon a knowledge of atmospheric conditions, aircraft configuration, weight, fuel supply, and fuel required for descent and climb, the computer could supply the pilot with data on range and endurance for a number of alternatives.

Besides supplying the primary, cruise-control information and flight-progress information, the coordinated cruise-control computer should be capable of advising the pilot concerning fuel management in case of emergency. In this role the computer on request can supply the pilot with information that may enable him to decide the best way of returning the aircraft safely.

#### Airplane Operating Limits

An airborne computer can help monitor the operating limits of the aircraft. In this role, the computer would inform the pilot when he is dangerously close to one of the operating limits of his vehicle. Also, it would monitor other subsystems, such as climb control, so that the commands would not exceed the design limitations of the aircraft.

The CAL study of applications of an airborne digital computer showed that during steady, level flight the operating limits could be monitored through the implementation of an altitude-Mach number plot as shown in Figure 3. At all times, the aircraft must operate in the shaded position of the plot.

To maintain operation in this portion of the plot, the following checks must be made. The low-altitude, structural limits of the vehicle can be monitored by computing an equivalent airspeed and comparing it with an allowable equivalent airspeed. At higher altitudes, where air-inlet temperature becomes important,

an allowable Mach number could be computed and compared to the present Mach number. At all altitudes, a computed minimum airspeed, based upon such quantities as present aircraft weight, would be compared to the present airspeed.

Other important applications for the central airborne computer are the bombing and navigation functions. The central data processor could also perform basic air data computations such as determining Mach number, angle of attack, true airspeed and other quantities from sensed air data. The possibility of using the computer as a numerical filter in numerous open and closed loop flight control subsystems appears to be especially attractive.

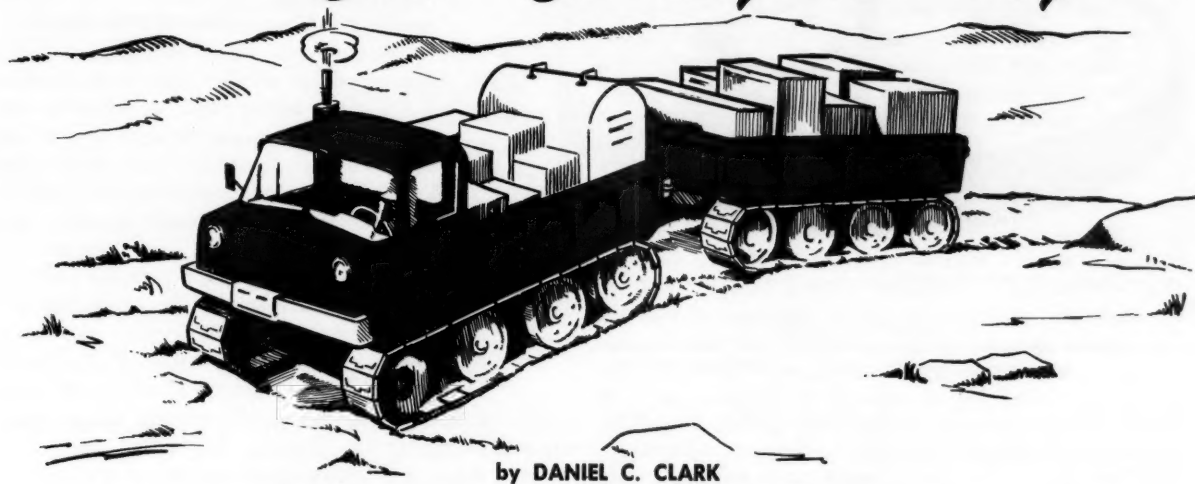
#### Computers in Space

The applications for the central digital computer which have been discussed up to this point have used manned aerial weapon systems as a frame of reference. Future space systems will have many of the same uses for the computer, and more. For example, the transition from non-aerodynamic to aerodynamic control during the re-entry of a space vehicle is extremely critical and must be carefully computed and controlled for the vehicle to survive. Re-entry paths must be computed and the autopilot must be capable of responding to the rapidly varying environmental conditions in addition to the coordination of the types of control.

Thus, one can surmise that the success of our future space flights may depend largely upon the ability of our digital computers and the men who design and program them. The digital computers in the research laboratories will materially aid the analysis of the space flight characteristics. Airborne digital computers, performing as integral parts of actual sampled-data systems, may improve the man-machine combination and make space flight more feasible.

## New Concepts for

# Cross-Country Mobility . . .



In recent years intensive research has been focused upon many forms of locomotion. Unfortunately, not much progress has been made in the field of cross-country locomotion, that is, travel over rough, variable terrain. Notwithstanding this lack of progress, cross-country mobility has become an increasingly important characteristic of tactical combat weapons and logistic vehicles as well as construction and agricultural vehicles.

Currently, the design of cross-country vehicles is performed almost entirely empirically; there have been developed very few vehicle concepts that might yield improved operation in cross-country tasks. No advanced theories of land locomotion dynamics, comparable to those of aerodynamics, now exist.

It would appear that the greatest progress in research in land dynamics has been in the analysis of the motion of pneumatic-tired vehicles over smooth roads and other non-deformable terrain. Accurately predicting the relationships of soil and vehicle on a deformable terrain — of the type encountered in cross-country locomotion — is a complex matter, due largely to the non-homogenous structure of the soil and the random variation of elevation with forward motion. The problems involved in accurately predicting these relationships have successfully evaded analytical solution for many years.

### Soil-Vehicle Relationships

The Land Locomotion Research Laboratory, U.S. Army Ordnance Corps, under the direction of Mr. M. G. Bekker, is expending much effort in developing a science of land locomotion and producing, in particular, an understanding of the relationships between vehicle elements and their geophysical environment.

The Vehicle Dynamics Department of the Cornell Aeronautical Laboratory has taken part in this effort by a study of the steering behavior of articulated track-laying vehicles in order to determine the feasibility of

the articulated steering concept. In addition, Cornell Laboratory has recently completed an internally sponsored program to investigate track-force mechanics in deformable soils.

The research is part of a total effort in the field of vehicle dynamics at CAL. The total program is concerned with the science of vehicles as a basis for improving current types and developing new concepts.

The present state of the art in track-force mechanics shows that it is possible to predict fairly accurately the resistance to forward motion and the total tractive effort of a track (or combination of tracks mounted on a vehicle) moving straight ahead on level, non-deformable soil. In the case of deformable soils, methods have been developed to predict motion resistance and tractive effort of a track moving straight ahead. For such prediction the characteristics of the soils must be known.

An equation has been proposed which contains three independent constants relating to vertical sinkage of a loading area. Shear strength of soils has been shown experimentally to depend on soil cohesion, friction and compactness. Two constants relating to the variation of passive earth pressure with depth have also been proposed.

So, in order to compute the longitudinal forces acting on a track moving straight ahead on a deformable soil, it is now necessary to evaluate experimentally no less than eight soil constants, each of which appears to be entirely independent of the others. No equations which predict the side force and yawing moment developed by a track maneuvering on a deformable soil have been found in the literature. This, then, is the present state of the art.

Equations have recently been developed at CAL, however, to express lateral track forces and yawing moment as a function of track motion variables. The work of Mr. Bekker in describing longitudinal track

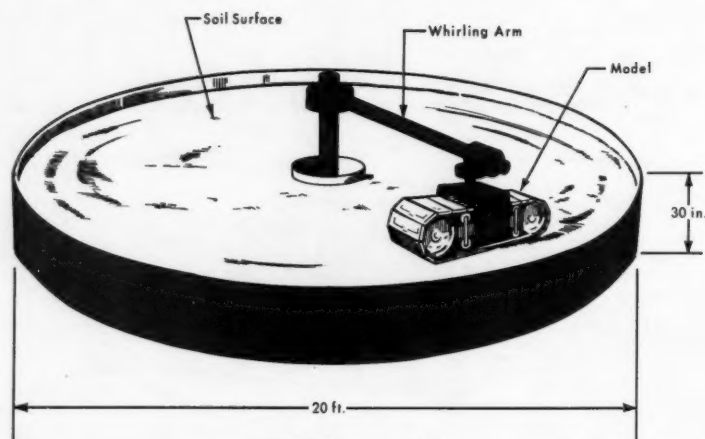


FIGURE 1 — Soil Bin  
Artist's conception of the CAL-proposed soil bin: a circular soil bin with model attached to a "whirling arm."

forces, when combined with CAL's newly developed yawing and side-slipping force relations, completely describes the macroscopic interaction of soil and track. Knowledge of soil-track relationships directly provides knowledge of soil-vehicle relationships, if track-vehicle relationships are known. The latter can be predicted with acceptable accuracy.

#### Development of Testing Facility

Experimental data are needed to substantiate these relationships. No facility capable of performing these experiments, however, exists today. Towing tanks, which have long been used for testing model ships experimentally, were adapted about a decade ago to use as soil bins. These soil bins provide a facility for deriving experimentally the force relations between soil and propulsion elements (wheels, tracks, skis, etc.).

The usual form of such soil bins is a long narrow container which has an overhead-driven carriage to tow the model longitudinally inside the bin. Proper instrumentation allows the longitudinal motion resistance of the model to be measured. This resistance can be related to full-scale resistance to motion by standard dimensional analysis techniques. If drawbar pull (total tractive effort minus motion resistance) is to be determined, a self-powered model is used, and the overhead carriage is used to simulate a towed load. All soil bins constructed to date have been designed for longitudinal force measurements only.

Since experimental verification of the new theory is obviously required before it can be used in design work, CAL has proposed a new concept in soil bins: a circular soil bin with the model attached to a "whirling arm" (See Fig. 1). This arm forces the model to move longitudinally and laterally, and to yaw in the plane of the soil bin. The conventional soil bin, when used with a properly instrumented circular soil bin, would facilitate the confirmation of the newly-developed theory. These soil bins would permit systematic study of the behavior of all vehicle elements which produce both tractive effort and guiding forces through the process of soil deformation.

#### New Cross-Country Vehicle Concept

Given a knowledge of the force and moment relations of soil and propulsion elements, the over-all kinematic behavior of both existing vehicles and new vehicle concepts can be examined theoretically.

One of the most successful vehicles developed for off-the-road transportation is the track-laying type. A properly suspended track is superior to a tire of the same vertical dimension and width (See Fig. 2) for use as a cross-country propulsive element for two basic reasons: distribution of the weight over a larger area results in lower ground pressure and less sinkage of the track; the track can develop tractive forces long after the tire is spinning, primarily because of the longer ground contact length of the track compared to that of the wheel. One large disadvantage exists in using tracks: they are difficult to steer.

As a means of improving the control of track-laying vehicles and simultaneously maintaining the narrow widths which have been found to give greater mobility, it has been proposed that the vehicle be articulated. Such a vehicle would consist of two track-laying units

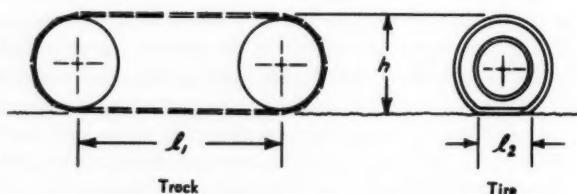


FIGURE 2 — Track-Tire Comparison  
Diagram shows superiority of track over tire of same vertical dimension ( $h$ ) and width;  $l_1$  and  $l_2$  represent the ground contact length of track and tire respectively.

joined together at a hinge or pivot point. Steering control would be accomplished by applying torques about the hinge in order to yaw the two units with respect to each other as shown in Fig. 3.

#### Cornell Lab Studies Steering Behavior

The performance of track-laying vehicles has not improved significantly in recent years, despite the steady increase in performance of the reciprocating engines. Since designs of cross-country vehicles long ago reached an advanced stage of development, the only hope of improving cross-country mobility lies in new vehicle concepts. Cornell Aeronautical Laboratory's study of the steering behavior of articulated track-laying vehicles for Land Locomotion Laboratory was a step in this direction.

In the recently completed CAL studies, a system of non-linear differential equations was developed to describe mathematically the turning performance of an articulated track-laying vehicle moving on hard, level ground. To implement their solution, an iterative



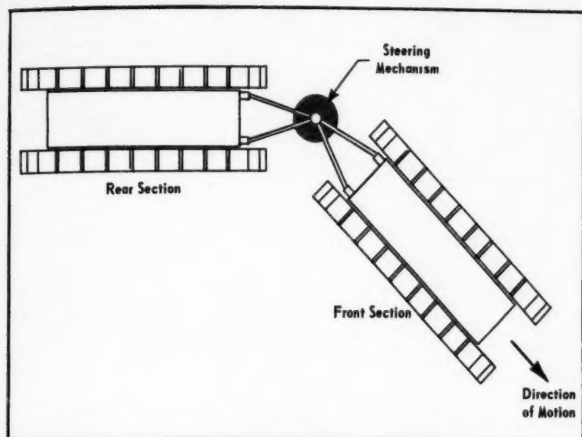


FIGURE 3 — View of Vehicle  
Plan view of an articulated track-laying vehicle. Steering control is accomplished by applying torques about the hinge.

computation procedure (based on the Newton-Raphson method using first order difference equations) was programmed into the IBM 704 digital computer facility at Cornell Laboratory. Studies were made of the turning behavior of a model articulated vehicle, and steady state solutions were obtained for a variety of vehicle geometrical configurations. Approximately 1500 solution points were obtained.

The use of digital computing equipment makes possible systematic design studies of the articulated vehicle for all values of centrifugal acceleration. Analysis can be further facilitated if attention is restricted to low centrifugal acceleration. At these low values the turning performance of a vehicle is determined primarily by vehicle geometry which causes path curvature response to be a linear function of articulation angle.

Experimental results obtained in former model tests confirm this theory.

Unfortunately these tests were conducted at speeds which do not provide a check of the behavior of the non-linear system at moderate and high centrifugal acceleration. The simplified equations demonstrate that a symmetrical vehicle (i.e., equal front and rear section lengths and weights) is the most desirable configuration with respect to steering hinge moments, power requirements, and steering stability.

#### Future Efforts

The articulated track-laying vehicle is a first step forward in the development of new vehicle concepts to improve cross-country mobility. This concept can logically be extended to what is probably the ultimate in cross-country vehicles: a many-section articulated vehicle which approaches the geometry of a snake. With multi-degree-of-freedom hinges, and independent steering control at each hinge, such a vehicle could be adapted to efficient locomotion over a wide variety of soil types and terrain profiles.

To substantiate existing theory, experimental programs should be initiated to confirm the basic soil mechanics which relate vehicle propulsive elements and soil. Only then can we be certain that future theoretical analyses will result in vehicle designs which will perform given cross-country tasks in an efficient manner.

#### REPORTS

"The Turning Behavior of Articulated Track-Laying Vehicles," Clark, Daniel C.; CAL Report YM-1230-V-5; Jan., 1959; 66 pages, (Land Locomotion Laboratory program).

"Track-Force Mechanics in Deformable Soils," Clark, Daniel C.; CAL Report YM-1198-V-1; March, 1959; 33 pages.

#### ABOUT THE AUTHORS

DR. MORTON G. SPOONER, Principal Engineer in the Electronics Department, has been studying the application of digital computers in large-scale systems ever since he joined CAL in 1956. Besides the study for I.B.M., outlined in his article, "The Airborne Computer," he has also been part of the team studying intercept control problems for the Navy.

Dr. Spooner came to CAL from the University of Wisconsin where he received his undergraduate and graduate degrees in electrical engineering. His thesis for the doctoral degree was "The Use of Correlation Techniques in the Study of Linear and Non-Linear Servo-Mechanisms."

He also was an Instructor and Assistant Professor at Wisconsin U. Earlier Dr. Spooner was employed as a refinery control engineer by the Standard Oil Co., Whiting, Ind.

He is a member of several engineering associations, including the American Institute of Electrical Engineers, the Institute of Radio Engineers and Sigma Xi.

DANIEL C. CLARK, author of "Cross Country Mobility," has been the project engineer on the two land locomotion studies outlined in his article. His background included earlier work in the field of vehicle dynamics: specifically, the electrical design and the engineering responsibility for the shake-down and calibration phases of a special vehicle program for General Motors.

Mr. Clark graduated from the University of Buffalo in 1955 with a B.S. degree in electrical engineering. He is now working on a Master's degree.

The Associate Research Engineer has been employed by the Laboratory since his graduation from U.B. He served first in the Instrumentation Section of the Flight Research Department. There he assisted in the design and shake-down phases of the T-33 variable stability aircraft program. He became a member of the Vehicle Dynamics Department in 1957.

Mr. Clark is a member of the Institute of Radio Engineers.



The Laboratory invites requests for its unclassified publications as a public service. Supplies of some publications are limited; and those marked with an asterisk may be distributed only within the United States. Please direct your request to the Editor, Research Trends, Cornell Aeronautical Laboratory, Buffalo 21, New York.

"SIMILITUDE OF HYPERSONIC FLOWS OVER THIN AND SLENDER BODIES — AN EXTENSION TO REAL GASES," Cheng, Hsien K.; CAL Report No. AD-1052-A-6; February 1958; 25 pages.

On the basis of the governing equations and boundary conditions, similitude in the hypersonic inviscid flow fields over thin or slender bodies is examined, wherein the restriction to ideal gas with constant specific heats is removed.

"TEMPERATURE LIMITS, RATINGS, AND NATURAL COOLING PROCEDURES FOR AVIONIC EQUIPMENT AND PARTS," Welsh, James P.; Reprinted from the IRE Transactions on Aeronautical Navigational Electronics, ANE-5, No. 1; March 1958; 10 pages.

This paper outlines the flow of heat within, through, and from heat producing electronic parts in terms of internal thermal limitations, part surface and environmental ratings, and cooling indices. Natural heat flow design data pertinent to conduction cooling of heat sources, tube shields, the placement and mounting of parts, and "sink connectors" are presented.

"LINEAR THERMODYNAMICS AND THE MECHANICS OF SOLIDS," Biot, M. A.; CAL Report No. SA-987-S-6; June 1958; 50 pages.

The Thermodynamics of linear irreversible processes is presented from a unified viewpoint. This provides a new and synthetic approach to the linear mechanics of deformation of solids, which includes as particular cases the classical theory of Elasticity, Thermoelasticity, and Viscoelasticity.

"THEORETICAL COMPARISON OF BINARY DATA TRANSMISSION SYSTEMS," Becker, Harold D. and Lawton, John G.; CAL Report No. CA-1172-S-1; May 1958; 69 pages.

Ground-Air data communication links are analyzed and compared on the basis of the error probability attained as a function of the received signal-to-noise ratio. For the case of frequency-shift keyed (FSK) modulation it is shown that the lowest error rate can be obtained by using a detector which incorporates two matched filters and a synchronized sampling and decision circuit.

"PROPAGATION OF WEAK WAVES IN A DISSOCIATED GAS," Moore, F. K.; Reprinted from the Journal of the Aeronautical Sciences, Vol. 25, No. 4; April 1958; 2 pages.

A recent paper has provided a study of the characteristic, or sound, velocity of a gas out of thermodynamic equilibrium. This note is concerned with a related topic — namely, the detailed study of the dynamics of weak, or acoustic, disturbances in such a gas.

"COMPUTED MOISTURE INTERCEPTION ON HELICOPTER ROTOR BLADES," Treanor, Charles E. and Williams, Marcia J.; CAL Report No. HB-973-A-1; June 1958; 63 pages.\*

The moisture impingement on an airfoil in free flight has been calculated by an automatic digital computer for three airfoil sections, for three droplet sizes, for a range of speeds up to 600 ft/sec, and for angles of attack from 0 to 12°. A method has been determined for combining the effects of free-stream Reynolds number and droplet size into a single parameter.

"AN ESTIMATE OF THE AERODYNAMIC HAZARDS OF ICE ACCRETIONS ON HELICOPTER ROTORS," Gail, Albert; CAL Report No. HB-973-A-2; July 1958; 18 pages.\*

Small ice accretions are identified as creating serious degradations of helicopter performance by increasing blade drag. Weight effects, lift spoiling effects, control degradation, etc., due to ice accretion are observed to be of minor importance compared to rotor drag increase.

"THE MONTE CARLO METHOD AS A DECISION AID IN AIRWAYS MODERNIZATION," Blumstein, Alfred; Reprinted from the National Conference on Aeronautical Electronics, Paper No. 71; 1958; 5 pages.

Techniques to investigate a broad spectrum of possible decisions on airways modernization are required. The decisions must be made before the new system is operational, and often before major portions even exist, so that abstractive rather than experimental techniques are called for. This paper introduces one such technique — the Monte Carlo method — to illustrate its application, and to evaluate its role in airways modernization.

"FLIGHT EVALUATIONS OF THE EFFECT OF VARIABLE SPIRAL DAMPING IN A JTB-26B AIRPLANE," Rhoads, D. W.; CAL Report No. TB-1094-F-1; October 1957; 83 pages.

A JTB-26B airplane was modified to permit in-flight variation of spiral stability over a wide range. Qualitative evaluations by two pilots of the relative acceptability of various spiral configurations were obtained for both instrument and contact type flying.

"COMPARISON OF BINARY DATA TRANSMISSION SYSTEMS," Lawton, John G.; Reprinted from the National Convention on Military Electronics Proceedings; 1958; 3 pages.

This paper compares the performance of binary transmission systems in the presence of additive white Gaussian noise from the aspect of the relative probability of error. Expressions for the error probability of coherent, non-coherent and "differentially coherent" systems are derived.

"FLOW IN THE VANELESS DIFFUSER OF A CENTRIFUGAL COMPRESSOR," Thompson, William E., Jr.; Illinois Institute of Technology Thesis; June 1958; 343 pages. (Only 25 copies are available.)

Assuming a model of inviscid free-stream flow and viscous boundary layer flow, several parameters are identified which may assist in defining diffuser losses. Distribution of pressure, Mach number, and flow direction were determined experimentally; temperature and velocity were deduced by a method due to Squire. Velocity profiles in both cylindrical and streamline coordinates are presented; radial distribution of displacement surface height is determined.

"STRUCTURAL DYNAMIC TESTS OF PROPELLER BLADES IN VACUO," Burquest, Marshall; Carpenter, James E.; and Sullivan, Edward M.; Reprinted from the Society for Experimental Stress Analysis Proceedings, Vol. 15, No. 2; 1958; 12 pages.

An apparatus for the experimental determination of static and vibratory structural characteristics of rotating scale model propeller blades was designed, fabricated, and made operational. Concurrently with the experimental program, a method for the analytical determination of the vibratory characteristics of the coupled flatwise-edgewise bending modes of rotating, twisted blades was developed.



